

NATIONAL SECURITY

Providing for National Security in a Changing World

Lawrence Livermore National Laboratory was established in 1952 to help ensure national security through the design, development, and stewardship of nuclear weapons. National security continues to be the Laboratory's defining responsibility.

The breakup of the Soviet Union brought an end to the Cold War. However, threats to international security remain, and global interests keep the United States actively engaged in world events. The U.S. is committed to halting the spread of chemical, biological, and nuclear weapons worldwide while maintaining sufficient nuclear forces to deter any adversary. The Laboratory contributes to these important endeavors.

Now a Part of the New NNSA

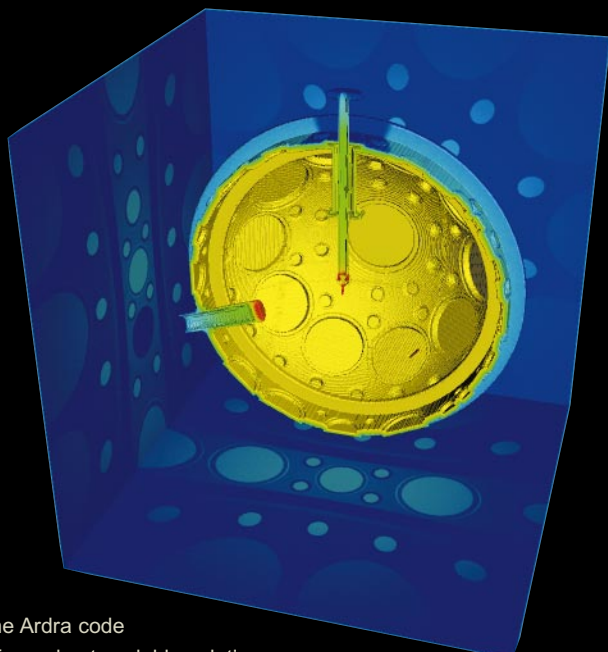
Livermore is one of three national security laboratories that are part of the new National Nuclear Security Administration (NNSA) within DOE. Created through Congressional legislation enacted in 1999, the NNSA formally starts operation in March 2000. The NNSA will bring together DOE's national security functions and give them a clear focus.

Safe and Reliable Nuclear Weapons

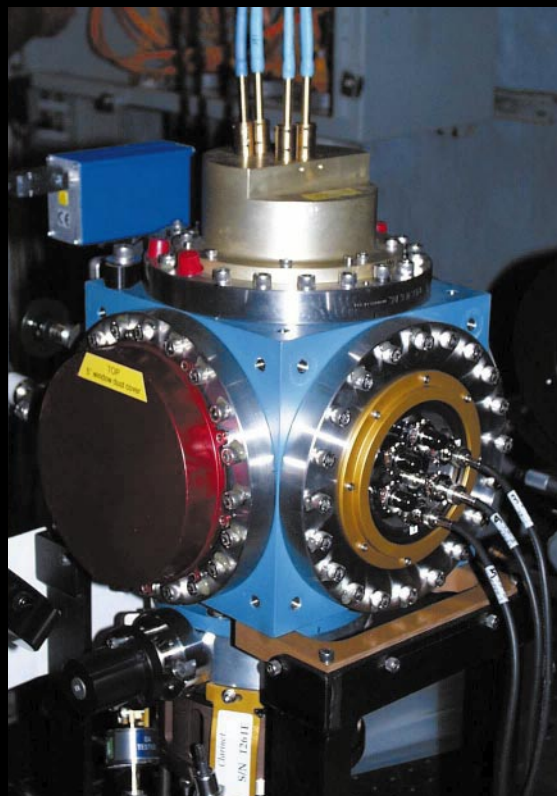
As one of the DOE National Nuclear Security Administration laboratories, Livermore plays a prominent role in the Stockpile Stewardship Program for maintaining the safety and reliability of the nation's nuclear weapons in the absence of nuclear testing. At the Laboratory, we are attending to the immediate needs of the stockpile by using a combination of laboratory experiments and computer simulations as a basis for performance assessments and certification. We are also acquiring more



Technicians assemble equipment used to dispose of plutonium from dismantled weapons. At Livermore's plutonium facility, we support the Stockpile Stewardship Program with basic research on the properties of plutonium so we can better understand how it ages and develop improved methods to process the material. The facility is also central to DOE's program to immobilize and dispose of excess U.S. plutonium.



The Ardra code offers robust scalable solution methods for neutron and radiation transport problems in three-dimensional geometries such as this calculation of a laser fusion target chamber.



This assembly was part of the subcritical experiment Clarinet, which was successfully conducted in an underground complex at the Nevada Test Site. It was the third in a series of experiments to study plutonium properties under extreme conditions.

powerful experimental and computational tools to address the more challenging issues that will arise as the nation's nuclear weapons stockpile continues to age.

Proliferation Prevention and Arms Control

The Laboratory is addressing the increasingly serious problem of the proliferation of chemical, biological, and nuclear weapons through a wide spectrum of analysis and technology development activities. In addition, Livermore provides the

government with technical information and assistance to support the development of national policy on nuclear weapons, nonproliferation, and arms control matters.

Technology for New Military Requirements

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and nonproliferation missions, Livermore develops advanced defense technologies for the Department of Defense to increase the effectiveness of U.S. military forces.

Stockpile Stewardship

Attending to Stockpile Needs

As a principal participant in the Department of Energy's Stockpile Stewardship Program, Livermore is committed to maintaining confidence in the safety and reliability of the U.S. nuclear weapons stockpile. The program is extraordinarily demanding because the nuclear weapons in the stockpile continue to grow older, and we are challenged to ensure their performance and refurbish them as necessary without conducting nuclear tests.

The Stockpile Stewardship Program integrates the activities of the DOE nuclear weapons complex, which includes Livermore, Los Alamos, and Sandia national laboratories as well as four production sites and the Nevada Test Site.

Certifying Stockpile Safety and Reliability


The objective of the Stockpile Stewardship Program is to provide the President of the United States with accurate assessments of the safety, reliability, and performance of each weapon system in the nation's nuclear stockpile. We provide these assessments through a formal annual certification process that relies critically on the expertise and capabilities of Livermore, Los Alamos, and Sandia national laboratories and their independent evaluations.

In 1999, the laboratories completed the technical reviews that provided the basis for the fourth certification of the stockpile for the President. Subsequently, the secretaries of Energy and Defense certified to the

President that the U.S. nuclear stockpile is safe and reliable and that no nuclear tests are needed.

Stockpile Stewardship Program "On Track"

In December 1999, a 30-Day Review of the Stockpile Stewardship Program concluded that the program's structure is "on track" and that "science-based stewardship is the right path." The review was commissioned by Secretary of Energy Bill Richardson to examine accomplishments and program structure to ensure that current and long-term needs for certifying the stockpile can be met. The specific findings of the review will help shape future decisions in the program to manage technical challenges and requirements, which will increase as the stockpile continues to age.



The technician (top) uses a solid-phase microextractor to collect samples of gases produced by organic materials in a weapon. The sample is then desorbed in the injection port (above and right) of a gas chromatograph-mass spectrometer, which identifies the compounds and measures their amounts. The analysis provides indications of material aging.



"The past year has been rough, but it is time to regroup and move forward with a strong focus on our mission," DOE Secretary Bill Richardson told Livermore employees in December. His visit followed high-level reviews of the Stockpile Stewardship Program and security improvements at the Laboratory.

Prior to the review, and with input from the laboratories and production facilities, the DOE Office of Defense Programs undertook a major shift in management strategy in response to evolving demands on the program. The revision recasts major elements of the Stockpile Stewardship Program into a set of activities that more clearly establish program goals and budget priorities and help to identify program risks if there are budget shortfalls. Integrated program activities include:

• **Directed Stockpile Work.**

These activities support the readiness of weapons and include activities to meet stockpile requirements. We have special responsibilities for the weapon systems that were designed at Livermore: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile.

• **Campaigns.** Campaigns are directed at making the scientific and technological advances necessary to assess and certify weapon performance over the long term without nuclear testing. Each of the 18 campaigns has well-defined, specific deliverables on which its research and development efforts are focused.

• **Readiness in Technical Base and Facilities.**

Readiness requires investments to be made in people, special experimental facilities, and supporting infrastructure to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future.

Refurbished Warhead Meets Requirements

In June 1999, Livermore's W87 Life Extension Program met the Air Force's Initial Operational Capability (IOC)



Now on Peacekeeper missiles, the W87 warhead/Mk21 reentry vehicle (RV) is a candidate for a single RV in the Minuteman III ICBM under the START II Treaty. Development activities to refurbish the W87 and extend its life included extreme environmental testing such as transportation and handling shocks, temperature changes, and missile launch and flight conditions.

requirement. The first refurbished unit was completed at the Pantex Plant in February 1999, and a significant number of refurbished W87 units have already been delivered. Refurbishment of the W87 ICBM warhead, the design with the most modern safety features in the stockpile, extends the lifetime of the weapon to beyond 2025. We completed all development activities, which have included flight testing, ground testing, and physics and engineering analysis. No additional nuclear

testing of the W87 is required to prove system reliability after the refurbishment. Assessment of nuclear performance is based on computer simulation, past nuclear tests, and new above-ground experiments that address specific physics issues.

Stockpile Stewardship

Modeling and Experiments

Decisions and actions about the stockpile must be grounded in experimental reality. In the past, that reality included nuclear testing. Now, we go about the business of ensuring stockpile performance using laboratory experiments and computer modeling to achieve a much more sophisticated understanding of underlying physics and engineering issues.

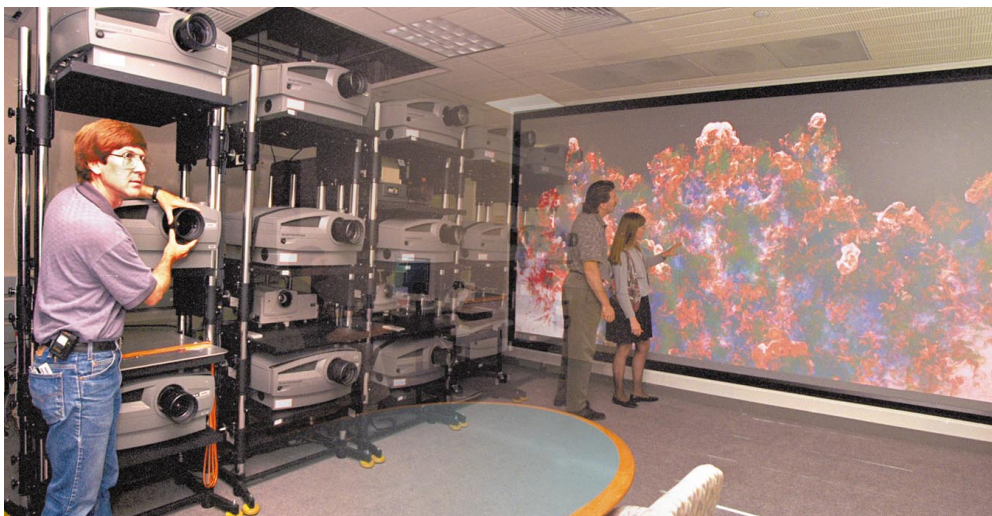
Understanding Plutonium

We are making significant progress in understanding plutonium, which is an extremely complicated material. To study the subtleties of this metal, we have combined advances in theoretical modeling of plutonium with the use of research tools made available through Stockpile Stewardship Program investments. We need to understand aging in

plutonium and the effect of aging-related changes on the performance of an imploding pit of a stockpiled weapon. Otherwise, we will not be able to accurately assess the lifetime of weapon pits and determine whether the nation must invest in new capabilities for plutonium operations.

One tool we use is subcritical testing at the Nevada Test Site. Livermore scientists are carrying out a series of experiments to investigate the properties of plutonium shocked and accelerated by high explosives. Matter can be ejected from the surface of materials that undergo shock. We are trying to characterize plutonium ejecta, which are thought to affect the performance of primaries in weapons. In 1999, we conducted three successful subcritical experiments: Clarinet in February and Oboe-1 and Oboe-2 in September and November.

We are using the Omega laser at the University of Rochester to conduct high-energy-density experiments while NIF is being constructed. Omega is similar to Nova in its ability to deliver energy to a target.



During the calculation of a nuclear primary explosion, 6 million megabytes of data were written in a total of 50,000 graphics files. Analyzing the generated data from the Blue Pacific supercomputer requires powerful visualization tools. The extremely high resolution and superior image quality of Livermore's Assessment Theater provide weapon scientists with detailed views of the results of complex simulations.

Unlike the previous experiments, the Oboe tests were the first to be performed inside individual confinement vessels. As a result, personnel are now allowed to enter the underground test chamber—the zero room—to retrieve films and data after the test, once the chamber is determined to be free of contamination. The use of vessels for subcritical experiments will result in significant cost reduction and improved data return. In the past, each subcritical experiment took a minimum of one year to field and rendered unusable all diagnostic equipment in the zero room.

We also will be carrying out accelerated aging tests on specially prepared plutonium samples. They include a mixture of isotopes different from that used in weapons-grade plutonium, so we will be able to accelerate the rate of self-irradiation damage, which is a key factor in aging.

3D Simulation of a Nuclear Explosion

As Secretary Richardson announced in December 1999, the first-ever three-dimensional simulation of a nuclear weapon primary explosion was completed using the Blue Pacific supercomputer at Livermore. The simulation is a major milestone in the Stockpile Stewardship Program and an important step forward in the full-system modeling of weapon performance.

Three-dimensional simulation is critically important because phenomena during a nuclear explosion—such as high-explosive detonation, hydrodynamics, and radiation transport—are not symmetric in many cases because of aging and manufacturing variations. To accurately model the interaction of these complex phenomena demands unprecedented computational capability.

The computer model that was used employs tens of millions of zones—hundreds of times more than a comparable two-dimensional simulation. The simulation ran a total of 492 computer hours and used 640,000 megabytes of memory (in contrast to tens of megabytes of memory in a typical desktop computer).

The work was completed through an intense, sustained effort that involved weapons code developers and computer support personnel at Livermore and from IBM. It required innovative three-dimensional algorithms able to represent the relevant physical processes and run efficiently on the Blue Pacific machine's parallel architecture.

Nova Ceases Operation

In July 1999, operations ceased at Livermore's Nova laser facility in order to bring online the National Ignition Facility (NIF), which will be

more than 60 times more powerful than Nova. High-energy lasers serve as experimental tools to generate data and validate simulation codes near—but not quite at—weapon-physics conditions. Until NIF operations begin, we are using the Omega laser at the University of Rochester to conduct high-energy-density experiments. Recent experiments at Omega have allowed a detailed comparison of two radiation transport models, with results that will be valuable for stockpile stewardship.

Stockpile Stewardship

Greater Capabilities to Come

The greatest challenges in stockpile stewardship lie ahead, as weapons continue to age. Program success depends on bringing into operation vastly improved scientific capabilities, which will be used by our experienced nuclear weapons designers to train and evaluate the skills of the next generation of stockpile stewards, who will rely on the new tools.

Supercomputer Comes of Age

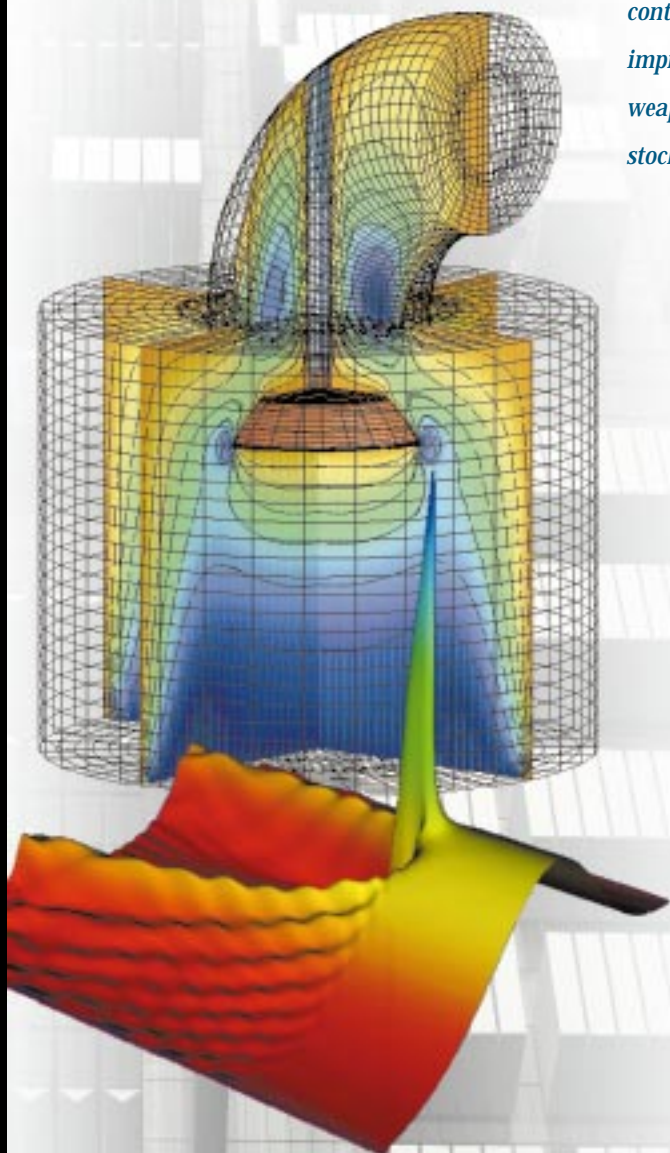
In a special ceremony on October 28, 1999, the Laboratory and IBM celebrated the "coming of age" of the Blue Pacific supercomputer with a special ceremony at Livermore. This machine, part of the Department of Energy's Accelerated Strategic Computing Initiative (ASCI), has been developed and delivered in several stages over the past three years. With all the critical elements now in place—software and code development, a functional problem-solving environment, interconnect and communications capabilities, and data storage facilities—Blue Pacific has become a mature tool for stockpile stewardship.

Created by IBM, Blue Pacific performs nearly 4 trillion operations per second, applying all of its 5,856 processors in parallel to a single computational problem. The supercomputer is 15,000 times faster than the average desktop personal

computer. In addition, the machine has over 2.6 trillion bytes (2.6 terabytes) of memory—80,000 times more than the average desktop personal computer—and could store all of the books in the Library of Congress.

The October ceremony highlighted breakthrough research calculations performed on the new machine and included a preview of Option White. Currently being built by IBM as an extension of Blue Pacific, this machine will be able to perform 10 trillion operations per second and will have three times the capacity of Blue Pacific. Option White is planned for delivery in summer 2000. It is the next step in a strategy of acquiring successively much more powerful supercomputers through ASCI.

The advanced computing capabilities at Livermore created by ASCI also offer the potential of leading to unprecedented levels of understanding in climate and weather modeling, environmental studies, the design of new materials, and many areas of physics.



Through the Accelerated Strategic Computing Initiative, Livermore is acquiring successively more powerful computers for stockpile stewardship. For DOE sponsors, we develop applications that run efficiently on the machines' massively parallel architecture. Simulations are shown of the dynamics of complex systems (top) and the interactions of intense laser light with plasma (bottom).

Pushing the NIF Construction Forward

Construction is under way at Livermore on the National Ignition Facility (NIF), a cornerstone of DOE's Stockpile Stewardship Program. This stadium-size complex will house the world's most powerful laser. With NIF, many of the fundamental processes of thermonuclear detonation will, for the first time, become accessible to laboratory study and analyses.

By firing its laser beams in unison and focusing its energy on a BB-size target for a few billionths of a second, NIF will generate the temperatures and pressures needed to conduct experiments to validate weapons-physics computer codes and address important issues of stockpile stewardship. NIF also will provide a powerful new tool for basic research into the physics of stars, high-energy plasmas, and fusion energy.

Construction of the NIF building complex will be completed in 2001 as initially planned, and installation of the laser infrastructure will be under way. We have achieved extraordinary success in many technology areas—from new production processes to make the required 150 tons of laser glass to techniques for rapid growth of extremely large crystals used for frequency conversion. The underlying



The 130-ton target chamber of the National Ignition Facility—which will house the world's most powerful laser—is shown being hoisted into place in the football-stadium-size building in June 1999.

science and technology of the project are sound. However, the project will take longer and cost more than initially planned.

In September 1999, Secretary Richardson ordered a series of actions to address the schedule and cost issues that have arisen. At the same time, we made significant changes in the Laboratory's NIF management team. The Secretary's actions included the appointment of a task force of the Secretary of Energy Advisory Board to review NIF.

The NIF Laser System Task Force concluded in its Interim Report that "... with appropriate corrective actions, a strong management team, additional funds, an extension of schedule, and recognition that NIF is, at its core, a

research and development project, the NIF laser can be completed." They added, "Several recent management changes as well as the new focus on systems engineering are encouraging."

We are committed to all actions necessary to ensure the success of NIF, which is an essential element of the Stockpile Stewardship Program. The new NIF project management team is developing a revised NIF project plan, and the project is proceeding.

Proliferation Prevention and Detection

The proliferation of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD) is a growing threat to U.S. and world security. Our program in nonproliferation, arms control, and international security is tackling the problem of WMD proliferation across the entire spectrum of the threat. We are involved in activities to prevent proliferation at the source, to detect and reverse proliferant activities, and to counter WMD terrorism.

Securing Russian Nuclear Materials

Through the DOE Materials Protection, Control, and Accounting (MPC&A) Program, we are working with Russia to secure weapons-usable nuclear materials at the sites that store, process, or use those materials. For example, Livermore leads the MPC&A team that is working with the Russian Navy and Icebreaker Fleet to improve the security of fresh fuel for these nuclear-powered vessels. Upgrades for two refueling ships were commissioned in September 1999. The upgrades included covers for the nuclear fuel storage racks that can be removed only with special tools and sensors and closed-circuit TV to monitor the storage area and nearby corridors. The excellent working relationship among the Russian Navy, the

subcontractor and system integrator (the Kurchatov Institute), and the highly trained team of DOE and national laboratory personnel is facilitating efficient problem solving and system implementation.

We lead the joint U.S.-Russian plutonium disposition activities to stabilize, immobilize, and geologically dispose of excess plutonium from Russian weapons. Industrial-scale immobilization of weapons-plutonium-containing materials is planned at one or more of the three plutonium processing sites in Russia by 2004. Livermore activities focus on supporting the industrial sites' plutonium immobilization requirements. We are developing and characterizing various immobilization waste forms for plutonium and examining the nonproliferation benefits of each.

Monitoring Improved for Nuclear Explosions

Livermore is part of a multilaboratory effort to provide the U.S. government with the R&D it needs to meet its worldwide nuclear explosion monitoring goals. Efforts are focused on seismic R&D for the

Before and after views of the nuclear fuel storage racks (left and right), showing the additional barriers to delay unauthorized access, on board a nuclear refueling ship for the Russian Icebreaker Fleet.



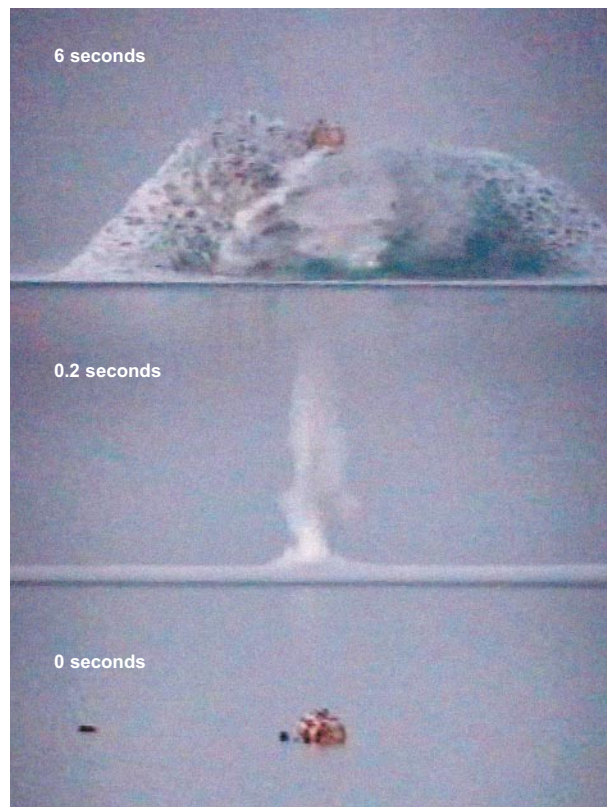
Our Center for Global Security Research sponsored a series of workshops on missile proliferation to bring together technologists and policymakers to discuss key issues. At the meeting in August 1999, the Honorable Donald H. Rumsfeld (far right), former Secretary of Defense and chair of the Rumsfeld Commission on Missile Proliferation, served as one of the panel chairs.

Middle East, North Africa, and Russia. We are working with Los Alamos and Sandia to construct a "knowledge base" that provides region-specific corrections to calculational algorithms used to locate and identify seismic events. This past year, we demonstrated that the knowledge-base concept will be able to meet U.S. monitoring goals. The locations of aftershocks from a large earthquake in the Caucasus Mountains were estimated and compared to data from published reports. Our region-specific corrections eliminated approximately 40 kilometers of bias from the estimates. Uncertainty of the aftershock locations was reduced to under 1,000 square kilometers (the limit for on-site inspections under the Comprehensive Test Ban Treaty).

We are also investigating nontraditional means of developing ground truth. From openly available satellite data, we are using pan-chromatic and synthetic aperture radar images to improve the level of ground truth in regions where physical access is difficult. For example, we are using radar data to directly identify mine collapses, which potentially are a major source of false alarms because data are similar to those of underground nuclear explosions.

New Sensors for Remote Monitoring

Chemicals associated with weapons of mass destruction (during R&D, production, testing, storage, or use) are released into the environment at levels that may be detectable by various technical means. We are developing a



An underwater 5,000-kilogram explosive was detonated in the Dead Sea in November 1999. Measurements taken at various locations in the Middle East are being used to calibrate seismic stations and improve DOE's knowledge base for the area.

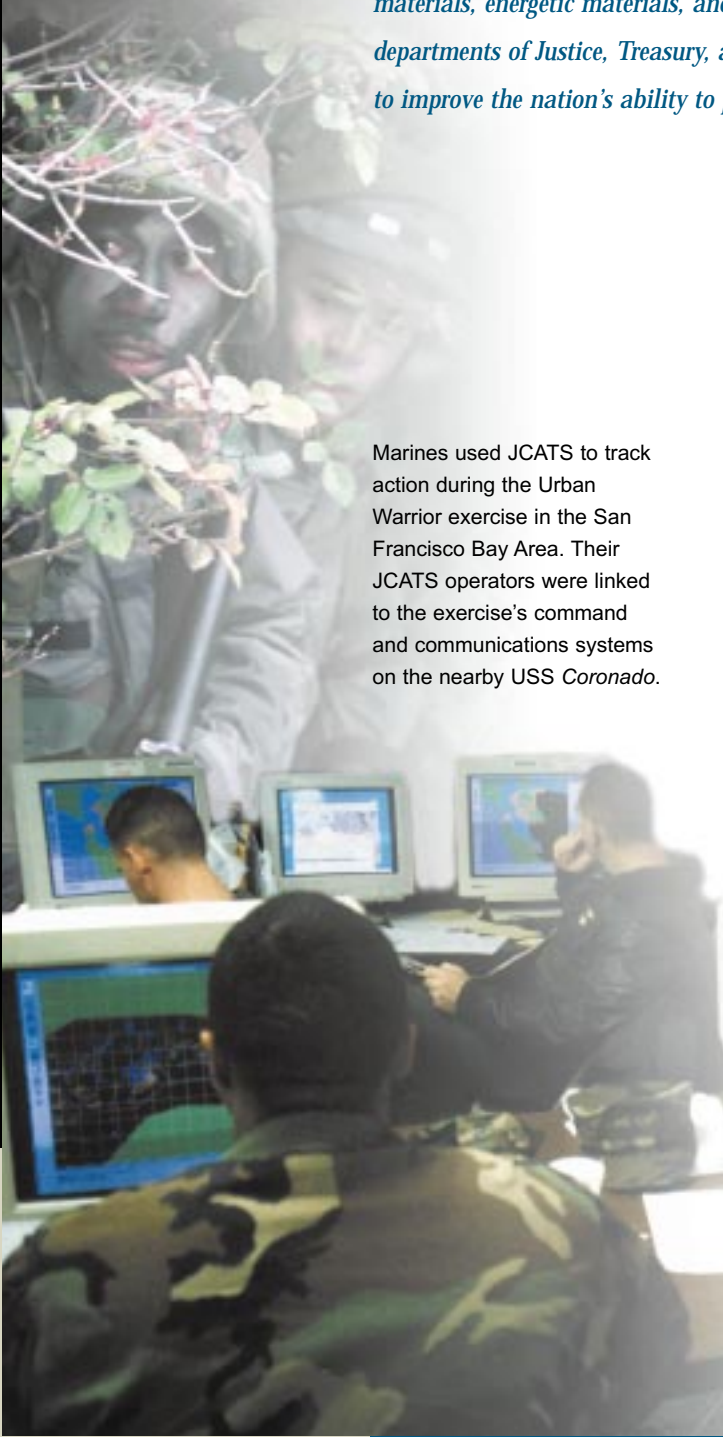
number of optical remote-sensing techniques for detecting, identifying, and quantifying signatures of the proliferation or use of weapons of mass destruction. Among these techniques are a hyperspectral infrared spectrometry system, a mid-wave infrared differential absorption lidar, and an echelle grating spectrometer (EGS).

We are exploring the use of the EGS for ballistic-missile defense applications. By looking at optical signatures following intercept of a hostile missile, we can use EGS to characterize in real time the impact debris and rapidly provide information about

enemy warheads containing chemical or biological agents. In a June 1999 field test of the concept, EGS performed flawlessly and returned useful booster plume and intercept signature information. As a result of this success, we are now funded by the Department of Defense to use EGS in the Intercept Flight Test Program to characterize intercept events.

Response to Proliferation and Other Security Threats

We work with the Department of Defense (DoD) to leverage the Laboratory's capabilities to meet a variety of national security challenges. In addition to our nonproliferation efforts, Livermore makes technological advances in such areas as missile defense, solid-state lasers, armor and antiarmor materials, energetic materials, and conflict simulation. We also work with other agencies, including the departments of Justice, Treasury, and Commerce, to respond to the 1998 Presidential Decision Directive to improve the nation's ability to prevent and mitigate attacks by terrorists using WMD.



Marines used JCATS to track action during the Urban Warrior exercise in the San Francisco Bay Area. Their JCATS operators were linked to the exercise's command and communications systems on the nearby USS *Coronado*.

Technology to Support Military Operations

In March 1999, two sophisticated computer tools developed at Livermore provided support to the Navy's Fleet Battle Experiment and the Marine Corps' Urban Warrior exercise. The Counterproliferation Analysis and Planning System (CAPS) provided real-time plume dispersal models associated with simulated chemical and biological attacks by terrorists against the 3rd Fleet and the City of Oakland. Used by U.S. combatant commands around the world, CAPS is an easy-to-use, powerful system for end-to-end process analysis of a proliferator's WMD production capabilities and for assessment of interdiction options and corresponding consequences.

The Joint Conflict and Tactical Simulation (JCATS) model supported Urban Warrior by providing a virtual

battlefield context for the Marine Corps' live exercise. The culmination of our long experience in conflict simulation, JCATS has become a standard for simulation activities used by more than 50 organizations—including U.S. military, the State Department, the Secret Service, and DOE's site-security function. JCATS allows training, planning, and tactics analysis from the campaign level (hundreds of square kilometers) to individuals fighting inside a multistory building. Version 2.0 of JCATS was delivered to the Atlantic Command's Joint WarFighting Center in October 1999.

Fast, Accurate, and Portable Biodetectors

As part of DOE's Chemical and Biological Nonproliferation Program, Livermore has developed unique instruments to dramatically advance biological agent detection capabilities. Our miniature flow cytometer uses our patented flow-stream-waveguide design, which



Applied on the left side of the petri dish, L-Gel effectively inhibits the germination of *Bacillus globigii* spores (surrogate for anthrax). Livermore's latest polymerase chain reaction (PCR) instrument (right), the HANAA, detects key biological agents.

permits the development of field-portable instruments. This past year, we demonstrated multiplex (simultaneous) detection of a suite of biological organisms and compounds (bacteria, bacterial spore, protein, and virus) using flow cytometry.

Two optimized polymerase chain reaction (PCR) instruments—the Advanced Nucleic Acid Analyzer (ANAA) and, most recently, the Handheld ANAA (HANAA)—have demonstrated a high probability of detecting even a single target DNA strand in a sample. Both instruments can detect key biological agents in 7 minutes, a breakthrough made possible through extreme miniaturization of the thermal cycling chamber. Versions of the ANAA have been delivered to the Naval Medical Research Center and the U.S. Army Medical

Research Institute of Infectious Diseases. The HANAA was delivered to its first users in December 1999. Each generation of our PCR instrumentation has been smaller, lighter, faster, and cheaper than the previous instrument.

Improved Chem/Bio Decontamination

Civilian first-responders have limited methods of chemical or biological decontamination—soap and water or bleach. Through DOE's Chemical and Biological Nonproliferation Program, we are developing a decontamination reagent that is effective against both chemical and biological agents, results in nontoxic byproducts, and is easy to use.

Livermore's L-Gel system is a fumed amorphous silica gel based on the commercial oxidizer oxone (with peroxy-monosulfate as the active

ingredient). L-Gel is noncorrosive and can be applied using a commercially available paint sprayer. It clings to walls and ceilings and does not harm carpets or painted surfaces. Laboratory and field tests over the past two years have demonstrated that L-Gel is effective on various materials found in a civilian setting against all classes of chemical warfare agents, sulfur mustard, all biological surrogates, and live vaccine strains.

Developing Lasers for DoD

In support of the Army's Space and Missile Defense Command, the Laboratory is working with industrial partners to develop a 100-kilowatt (average power) solid-state laser to be deployed on a mobile battlefield platform. Such high-power laser systems are leading candidates for an enhanced air-defense

capability. In 1999, we developed 1.5- and 10-kilowatt prototype lasers and tested their effectiveness in damaging selected materials. We plan to deliver the 10-kilowatt prototype to the High-Energy Strategic Test Facility (HELSTF) at White Sands Missile Range in 2001.